Shipboard Data Assimilation System/Doppler Radar

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LONG-TERM GOALS

Develop a high-resolution data assimilation system that can provide an analysis of the atmosphere with sufficient details and accuracy that it can be used to support the Navy mission in threat detection, weapons, and weather safe operations. The system will utilize all available weather information, such as Doppler radar, in situ, and remotely sensed observations, to generate a detailed analysis of the atmosphere with sufficient accuracy to predict EM/EO propagation and potential weather target conditions. This information can then be fed back to the SPY-1 radar and other weather systems, to give them lower threshold detection capability.

OBJECTIVES

Build a data assimilation suite around the Coupled Ocean/Atmospheric Mesoscale Prediction System (COAMPS). This data assimilation system will be able to analyze mesoscale weather by applying sophisticated analysis procedures capable of ingesting the information from Doppler radar, mesonet, and remote sensors. The primary focus of this effort will be to design a system that optimally utilizes the available weather information such as SPY-1 Doppler radar for COAMPS.

APPROACH

The mesoscale data assimilation system will use the background fields provided by the atmospheric component of COAMPS predictions on non-synoptic time levels and by the newly developed NRL 3DVAR on the synoptic time levels. Simplified adjoint methods will be used to achieve high computational efficiency to assimilate high resolution data from Doppler radars (including SPY-1) and satellites in four dimensions (space and time). The analysis increment fields will be expressed by B-spline expansions to optimally filter noise while the analysis is performed directly on the COAMPS grid. The assimilation time window will be synchronized with COAMPS integration time steps and radar volumetric scans to enhance the coupling of the model with the data.

Since Doppler radar measurements are limited to reflectivity and radial-component wind in stormy areas and/or boundary layer within the range of radar observations, using radar information alone may not be sufficient for the proposed high-resolution data assimilation. It is necessary to combine the radar observations with other high resolution observations not used by 3DVAR (such as the GOES cloud imageries and sounders, and lightning data). A cloud analysis package using GOES (and other remotely sensed) observations will be developed and incorporated into the data assimilation system.

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WORK COMPLETED

Obtained SPY-1 data from Lockheed Martin, and modified their universal-format data-reader source code into a data ingest package for our analysis and retrieval. Further modified the Simple Adjoint Algorithm code for SPY-1 Doppler wind retrieval on conical surface, and verified the retrievals against the dual-Doppler analysis using the KDIX radar NEXRAD LEVEL II data obtained from NCDC.

The 3DVAR has been expanded to analyze TOVS radiances directly. It runs the complex quality control on data and is being tested with the global and mesoscale prediction systems, NOGAPS and COAMPS, respectively.

The cloud analysis algorithm developed at the NOAA Forecast System Laboratory is being modified and incorporated into the ARPS Data Analysis System (ADAS) at the Center for Analysis and Prediction of Storms (CAPS), the University of Oklahoma. The algorithm is designed to construct three-dimensional cloud and precipitation fields from GOES infrared and visible imagery data in combination with radar reflectivity, surface cloud reports, and Aviation Routine Weather Reports (and lightning data, included recently). To test the impact of the ADAS cloud analysis to COAMPS analysis and prediction, a data-transfer package is developed to superimpose the ADAS analysis onto the current COAMPS analysis code, based on the multivariate optimum interpolation method.

Performed test runs of COAMPS to examine the impact of mesonet, (NEXTRAD) radar, and GOES data (through ADAS cloud analysis) on the short-term storm prediction. Based on these tests, the originally outlined strategy for the development of "Mesoscale Data Assimilation System Using Doppler Radar" is further consolidated. In particular, the variational wind retrieval scheme is reformulated into incremental form to enhance the consistency of the analysis with COAMPS background fields. The wind retrieval codes are modified and upgraded to adapt to the COAMPS terrain following staggered grid. The upgraded codes also consider the movement of the shipboard radar.

RESULTS

When the SPY-1 data were collected by Lockheed Martin for the 21 August 1996 rain storm over the eastern coast of US, the purpose was to make direct snapshot comparisons with the NEXRAD observations rather than for wind retrieval or data assimilation studies. Because of this, SPY-1 data suitable for wind retrieval or COAMPS data assimilation are virtually not available so far. Regardless of this difficulty, one short sequence of three rapid snapshots was selected from the existing SPY-1 data and used for wind retrieval studies. Since the data became very sparse above the lowest three elevations, the Simple Adjoint Algorithm code had to be modified to retrieve the vector wind field directly on the conical surfaces (instead of model's grid). The results so far obtained are very encouraging. Even though the SPY-1 data cover only the lowest three elevations and are available for only three consecutive scans, the retrieved vector wind field can capture the flow pattern verified by the dual-Doppler analysis using the KDIX radar NEXRAD LEVEL II data.

Performed test runs of COAMPS to examine the impact and added value of observations from (NEXTRAD) radar, surface mesonet, and GOES (through ADAS cloud analysis) on the short-term storm prediction. The results show that adding the mesonet data into the analysis (through ADAS) can improve the short-term storm prediction of cloud and precipitation, adding the GOES data (through ADAS cloud analysis) further improves the prediction, and adding the Doppler radar data retrievals in combination with mesonet data even further improves the prediction. Both the fine grid (5 km) and

relatively coarse grid (15 km) COAMPS background fields have been used in the analyses and test runs. However, since the ADAS analysis was not updated through data assimilation cycles, the analysis with the fine grid (5 km) COAMPS background field suffered a phase-error problem (due to the mismatch between the model background and observation in terms of the position and structure of the storm). Because of this, the improvement was most significant in the prediction when the 15 km COAMPS background field was used in the analysis.

IMPACT

This research will lead to a significant improvement in the quality of the COAMPS on-scene atmospheric environment analysis and forecast as a result of the newly developed assimilation of the high resolution Doppler radar data in combination with all other available weather information. Improvements in Shipboard COAMPS translate to improved mission support and cost savings for the Navy.

TRANSITIONS

The algorithms and computer codes developed from this project will be integrated into COAMPS. Extensive tests will be performed and then the new codes will used in 6.4 programs (PE 0603207N) for applications within TESS/NC and, via the TESS/NC - JMCIS link, with the tactical applications supporting on-scene decision makers.

RELATED PROJECTS

Related 6.2 projects within PE 0602435N are BE-35-02-09, for Data Assimilation and Analysis, BE-35-2-19, for Data Assimilation Techniques and Quality Control for On-scene Analysis/Prediction System, BE-35-02-18, for the development of Atmospheric Mesoscale Models, and BE-35-2-21, for the development of advanced visualization techniques. The related 6.4 project under PE 0603207N is X2343-10, which focuses on the transition of the 6.2 development to the STAFC demonstration project.

PUBLICATIONS

Xu, Q., J. Gao, and W. Gu, 1998: Generalized adjoint for physical processes with parameterized discontinuities – Part V: Coarse-grain Adjoint and Problems in Gradient Check. ***J. Atmos. Sci***., **55**, 2130-2135.

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